IMPLEMENTATION PLAN

VIRGIN ISLANDS/FLORIDA INVENTORY & MONITORING PROGRAM

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EXECUTIVE SUMMARY

The Biological Resources Division (BRD) of the U.S. Geological Survey (USGS) and the National Park Service (NPS) are collaborating on an Inventory and Monitoring (I & M) Prototype Program for national parks in 10 broad biogeographic associations that encompass most of the parks with significant natural resources. Virgin Islands National Park (VIIS), Buck Island Reef National Monument (BUIS) and Dry Tortugas National Park (DRTO) together were selected to represent the tropical/subtropical biome. These parks form a logical grouping of island environments with remarkable biodiversity and similar management concerns. BRD scientists are working with NPS resource managers and others to complete the most critical inventories for these parks and to establish effective long-term monitoring programs. The Virgin Islands/Florida I & M program focuses on coral reefs, seagrass, and dry forest ecosystems, reef fishes, sea turtles, birds, and water quality, and the effects of natural and anthropogenic stresses on these. Dry Tortugas National Park serves as a "reference" site (although not an exact "control" site) for marine ecosystems which are under more stress in the Virgin Islands (and elsewhere in the Florida Keys). For example, sedimentation associated with coastal development is a primary threat to reefs in VIIS but not in DRTO. Monitoring is necessary to detect and evaluate long-term trends in the structure and function of marine and terrestrial systems and the associated populations of endangered and otherwise significant species within these three parks to provide a basis for educated management. The monitoring activities presented in this document are designed to address specific management concerns for these parks including, 1) the effects of development and increased visitation on terrestrial and marine ecosystems, 2) effects of hurricanes, droughts, and other natural stresses on marine and terrestrial resources, 3) effects of fishing on fish assemblages and associated reef systems, 4) effects of soil erosion (VIIS only), and, 5) the status of rare, endangered and endemic species. The overall goal is the development of a series of protocols to serve as a basis for an operational monitoring program which will become the responsibility of the National Park Service after the developmental/ design phase is completed by BRD. At current staffing and funding levels, full implementation of the comprehensive program described here will not be possible. The primary emphasis of the scaled-back program will be on monitoring of marine ecosystems, sea turtles, and water quality. NPS and BRD are developing a more specific plan to facilitate the transition from the developmental phase to the operational phase of the program.

INTRODUCTION

In 1992, the National Park Service (NPS) began an Inventory and Monitoring (I&M) Program to gather baseline information and develop monitoring methods to better understand the natural resources in national parks. A primary goal of this program is to implement long-term monitoring in 10 broad biogeographic associations (or "biomes") that contain most of the 250 parks with significant natural resources (NPS 1995a). In 1993, scientists and resource management specialists in Virgin Islands National Park submitted a joint proposal for Virgin Islands National Park (VIIS), Buck Island Reef National Monument (BUIS), and Dry Tortugas National Park (DRTO). Through a competitive process, the proposed monitoring program was selected as the prototype for the tropical/subtropical biome. The NPS scientists based in VIIS were transferred to the National Biological Survey in 1993 and then, in 1996, to the Biological Resources Division (BRD) of the US Geological Survey (USGS). The prototype program is a collaborative effort between NPS and BRD, with the BRD scientists responsible for the design of the long-term monitoring programs over approximately the next five years. This Implementation Plan reflects priorities identified in the 1993 proposal which was accepted for funding under the I & M program as well as priorities identified in the Resource Management Plans for these parks and in meetings with park Superintendents, Biologists, and Resource Management Specialists.

Virgin Islands National Park, Buck Island Reef National Monument and Dry Tortugas National Park (formerly Fort Jefferson National Monument) together form a logical grouping of parks with remarkable terrestrial and marine biodiversity and similar management concerns. These three protected areas encompass entirely insular environments with subtropical-temperate (Dry Tortugas) and tropical (US Virgin Islands) conditions. Fort Jefferson National Monument, located about 110 km from Key West, Florida, became the world's first marine protected area when it was established by Presidential Proclamation in 1935. The Monument became Dry Tortugas National Park in 1992. Virgin Islands National Park was established on St. John, U S Virgin Islands, in 1956 with the addition of the marine portions in 1962. Buck Island Reef National Monument (St. Croix, USVI) was designated in 1961. In 1976, VIIS and DRTO were both designated as biosphere reserves, two of the first protected areas in the U.S. to receive this recognition. Only about 30 of over 311 international biosphere reserves contain both marine and terrestrial portions. VIIS consists of 2947 hectares (ha) of land on the island of St. John and 2287 ha of surrounding waters, while BUIS includes the 72 ha on Buck Island and 283 ha of nearshore waters. About 99% of DRTO's 26,200 ha is water and submerged lands (the Dry Tortugas Banks).

All three of these parks contain coral reefs, seagrass beds, algal plains, and mangroves; and provide habitats for endangered sea turtles, birds, fishes, and other species of special concern. All are relatively dry environments; VIIS is the only one of the parks which has streams, and these are ephemeral. The climate at Dry Tortugas is subtropical from spring through the fall, but winters often bring cold fronts which depress air and water temperatures. The annual variation in sea water temperatures is about 10 degrees Celsius in Tortugas but less than 5 degrees C in the Virgin Islands. While the Dry Tortugas are low islands formed by marine-sedimentary processes, the Virgin Islands are relatively high in elevation with geological features of uplifted metamorphic rock. The steep hillsides of St. John and increasing development create the potential for more damage to natural resources than in the other two parks.

Significance of Natural Resources of VIIS, BUIS, and DRTO

The enabling legislation for each of these protected areas recognizes the significance of their marine resources, with specific mention of coral reefs. These coral reefs and nearby seagrass beds support a high diversity of fishes, endangered sea turtles, conchs, lobsters, and other organisms. Dry Tortugas National Park serves as a "reference" site (if not an exact "control" site) for marine ecosystems which are under more stress (from sewage, sedimentation, and visitation) elsewhere in the Florida Keys and the Virgin Islands. The marine environment of DRTO is less disturbed by human activities than any other coral reef ecosystem in North America. Although far north, the reefs possess a full complement of Caribbean coral species. The diversity of fish species may be unsurpassed on the Atlantic Coast of the United States.

The 1992 legislation which created DRTO also specifically mentions protection of sea turtles and sea birds. The Spanish explorer Ponce de Leon visited in 1513 and named the islands Las Tortugas ("The Turtles") after his crew captured 160 green turtles in just one day. Results of the 1996 sea turtle monitoring program in DRTO suggest that DRTO may host one of the largest concentrations of nesting green turtles in the continental U.S. Loggerhead turtles nest there in far greater numbers. Buck Island is one of the most significant hawksbill nesting areas in the Caribbean.

The forests on St. John and Buck Island contain a high proportion of native species and represent remnants of the once-widespread tropical dry forest ecosystem in the Caribbean, the only ones which are under U.S. protection. Most of the remaining dry forest habitat which can be found on other islands is vulnerable to development. A few areas on St. John may contain undisturbed portions of the original forests. The dry forests on Buck Island and St. John represent secondary forests which have been allowed to recover under NPS protection.

Recent studies of the birds on St. John have led to the discovery that the island supports very high densities of migratory warblers. The relatively intact forests of St. John provide habitat that is no longer found on most other Caribbean islands. Virgin Islands National Park is perhaps the only significant wintering area for migratory warblers under NPS jurisdiction.

Dry Tortugas National Park is world-renowned for its bird life. The outstanding natural values of the area were first officially recognized in 1908 when an Executive Order created a wildlife refuge primarily to protect the Sooty Tern colony, which had been nearly decimated by egg collectors. The park currently has the only nesting colonies of Magnificent Frigatebirds and the most significant Sooty Tern and Brown Noddy colonies in the continental U.S.

CONCEPTUAL FRAMEWORK FOR VI/FLORIDA I & M PROGRAM

The overall goals of this prototype I & M program are to complete the most essential inventories for VIIS, BUIS, and DRTO and to develop the structure for long-term monitoring programs. This I & M program emphasizes monitoring rather than inventories. While additional information on the status of organisms in these parks would be valuable and efforts will be made to complete the most critical inventories, most inventories are essentially complete. Monitoring is necessary to detect and evaluate long-term trends in the structural and functional attributes of the marine and terrestrial systems and the associated populations of endangered and otherwise significant species within VIIS, BUIS, and DRTO to provide a basis for educated management. The monitoring program for these three parks is envisioned at the ecosystem, watershed, community, and species level (population) scales. The programs are more comprehensive for BUIS and VIIS but include the highest priority marine resources in DRTO (coral reefs, reef fishes, sea birds, and sea turtles).

The overall conceptual framework for this program reflects the influence of natural and human-caused stresses on coastal ecosystems (marine and terrestrial) and the link between upland or upstream and downstream processes. It is the combination of these stresses which managers must come to terms with, and the long-term monitoring programs for these three parks must take into consideration the complex relationship between the effects of natural processes and human activities (recreational and others). While it is true that hurricanes and other natural stresses can not be "managed", it is also true that one cannot understand the current status of the ecosystems in these three parks without considering the major hurricanes and storms which have affected them in the last 1 - 2 decades.

Protocols

The foundation of the program will be the design and production of a series of protocols within one conceptual framework. Existing protocols will be fine-tuned, and new ones will be written as necessary. Each protocol will include a statement of the objectives for each inventory or monitoring activity as well as quality control/quality assurance procedures. The design of any monitoring program requires identification of the temporal and spatial scales appropriate to the questions which are being asked. Identification of these scales will determine the number of samples, the locations, and the frequency of sampling. (See also Protocol Development/Evaluation/Selection below).

Determination of Priorities

Priorities for inventory and monitoring in all three parks were presented in the 1993 proposal and were drawn primarily from Resource Management Plans, research reports and publications, and discussions with NPS scientists and resource managers. At a meeting in March 1996, participants from all three parks agreed that the highest priorities remained essentially as presented in the 1993 proposal. (A few of the recommended studies have been completed since the proposal was first accepted, and new threats in some cases have required a shift in emphasis.) In July 1997, Everglades

National Park scientists and BRD scientist Caroline Rogers met to discuss the development of a Science Plan for DRTO and confirmed that the I & M priorities for the park remain essentially the same as in the 1993 proposal.

The VI/Florida I & M Program will focus on coral reef, seagrass, and dry forest ecosystems, reef fishes, sea turtles, birds, and water quality, and the effects of natural and anthropogenic stresses on these. This Implementation Plan presents more than can possibly be accomplished at the anticipated staffing and funding levels for the program (levels which are, in turn, far less than in the 1993 proposal). However, if additional funding becomes available, this document provides guidance on priorities for future projects.

Proposed Monitoring Activities

The monitoring activities presented below are designed to address specific management concerns, including the following:

1.) effects of development and/or visitation on terrestrial and marine ecosystems
Is the level of visitation at VIIS, BUIS, and DRTO causing serious damage to park ecosystems or species (e.g., anchor damage to coral reefs, disturbance to sea bird colonies)? Is the continued development of St. John contributing to the degradation of dry forests and coral reefs around the island? Is it jeopardizing the winter habitat for migratory birds? Has the installation of mooring buoys in some St. John bays allowed recovery of seagrass beds?

2.) effects of hurricanes, droughts, and other natural stresses on marine and terrestrial resources
The natural resources in the US Virgin Islands have been hard hit by Hurricanes Hugo (1989), Luis and Marilyn (1995), and Bertha (1996). A drought, the most severe in the last 70 years, occurred on St. John in 1994-1995. Although DRTO largely escaped the devastation of Hurricane Andrew (1992) it was hit by the “Storm of the Century” in March 1993. Winter cold fronts have caused massive mortalities of corals in DRTO, for example in 1962 and 1977. New coral diseases appeared on reefs within VIIS and DRTO this summer with potentially serious consequences.

3.) effects of fishing on park species and ecosystems
How can reef fish assemblages and traditional fisheries be maintained in BUIS and VIIS? Are current levels of fishing in BUIS, VIIS, and DRTO sustainable? How has fishing pressure affected abundance and size of target species?

4.) effects of development and/or visitation on water quality (including nutrient concentrations)
Are levels of nutrients, sediments, and bacteria in waters around the parks increasing to unsafe or undesirable levels or contributing to degradation of coral reefs in VIIS, BUIS, or DRTO? What are the sources of these sediments and pollutants?

5.) effects of soil erosion from unpaved roads, clearing of vegetation, and other development on VIIS resources

Is sediment input to marine waters increasing significantly because of increasing development and, if so, a) is water quality deteriorating? b) are reef corals or seagrasses dying?

6.) the status of rare, endangered and endemic species

Park managers need information on the status of marine and terrestrial species of special concern, including endangered sea turtles, plants and birds. For example, is increasing visitation at Buck Island adversely affecting sea turtle nesting beaches? Are sea bird colonies at DRTO being severely disturbed by the increasing numbers of boats and seaplane trips to the park?

7.) inaccessibility of existing data for use by NPS and other managers and scientists

We intend to establish data management protocols for DRTO, BUIS, and VIIS to improve the organization and accessibility of large amounts of existing data and to ensure that additional data which are collected can be analyzed and retrieved (see section below on Data Management). The Geographic Information System (GIS) at VIIS should eventually be helpful in integrating much of the data for specific long-term monitoring sites. A primary objective is to make research results readily available to park managers, for example, by preparing summaries of existing research at each of the parks.

History of Research in VIIS, BUIS, and DRTO

Any long-term inventory and monitoring program relies heavily on existing information. The information must be readily accessible. One objective of the VI/Florida I & M program is to develop or update documents which summarize and synthesize relevant information on natural resources in the three national parks. In 1996, the NPS I & M program provided the necessary support to compile pertinent documents on VIIS, BUIS, and DRTO on ProCite, a computerized bibliographic software program. These bibliographies provide a good starting point for comprehensive syntheses of pertinent natural resource information for each of the parks.

<u>Virgin Islands National Park</u>

Much of the baseline information for VIIS comes from a series of reports produced by the Virgin Islands Resource Management Cooperative from 1983 to 1988. They are summarized, along with earlier reports and publications, in Rogers and Teytaud (1988), which serves as an ecological history for the park through the late 1980's. From 1958 to 1961, a series of studies focused on fish taxonomy and ecology (listed in Randall

1961). The Tektite I and Tektite II underwater habitat projects took place in Great Lameshur Bay (on the south side of St. John) from 1969-1971 (Collette and Earle 1972, Earle and Lavenberg 1975). These studies included research on lobsters, algae, fishes, and coral reef biomass. A series of reports, publications, and doctoral theses prepared in the late 1980's through the present describe long-term monitoring efforts on marine and terrestrial ecosystems and the effects of several recent hurricanes, the effects of fishing, the feasibility of dry forest restoration, and other investigations (e.g., Ray 1993, Reilly 1991, 1994, Dallmeier et al. 1993, Rogers et al. 1991, 1997). There is a need for an updated summary of the work done since the Rogers and Teytaud (1988) document.

Buck Island Reef National Monument

No synthesis of research exists for Buck Island. However, an annotated bibliography lists reports and publications from marine studies of the island dating from 1977 to 1992 (Gladfelter 1992). Scientists at West Indies Laboratory, located on St. Croix for about 20 years before it was destroyed by Hurricane Hugo in 1989, have published numerous excellent papers on the biology and geology of Buck Island (see Gladfelter 1992). A summary of research which has been conducted on sea turtles appears in Hillis (1997).

Dry Tortugas National Park

An excellent annotated bibliography for DRTO will soon be available on the Internet and in hard copy (Schmidt and Pikula 1997). It contains many of the reports available on the Dry Tortugas up through 1996. The earliest documented marine research around Dry Tortugas was conducted by Louis Agassiz who published a map of the area's reef system in 1882. In 1904, the Carnegie Institution established a marine laboratory on Loggerhead Key. The lab was world-renowned for its pioneering work on coral reefs. By 1939, 35 volumes of research had been published by the Tortugas lab.

The National Park Service and Florida Marine Research Institute (FMRI) have produced a series of especially valuable reports on the reefs and lobster populations within the park (e.g., Davis 1977, Jaap and Wheaton 1995) which are referred to in greater detail below. Recently several studies have been initiated in conjunction with the establishment of the Florida

Keys National Marine Sanctuary, including those on water quality, lobster populations, and seagrass beds.

INVENTORIES

Tables 1, 2, and 3 present the status of inventories for major natural resources in VIIS, BUIS, and DRTO. In many cases, these inventories were the initial phases of monitoring programs which continue today. One overall objective is to provide an "inventory of inventories", i.e., a comprehensive list of what information is available in the form of maps, slides, photographic prints, and collections using ProCite.

Marine Inventories

Benthic (Bottom) Maps

Benthic maps are available for all three parks. The first map of the marine communities around St. John appeared in Kumpf and Randall (1961). Later, Beets et al. (1986) produced 16 maps, based on aerial photographs and field observations, and described all of St. John's bays. Similar maps were produced for Buck Island (Anderson et al. 1986). Each of these maps indicate major marine ecosystems and their subzones and have been entered in the VIIS GIS. Although these maps have been an excellent source of information for park managers and scientists, they are based on tracings of aerial photos and not georeferenced. In September 1996, Dr. Chuck LaBash of the Univer. of Rhode Island worked with Dr. Beets to produce corrected, digitized maps and to digitize bathymetry data for waters around the island of St. John. Plans are underway to create a digitized map of benthic zones around BUIS under a Cooperative Agreement between NPS and the Virginia Institute of Marine Sciences.

The need for a benthic community classification and map has been identified as a priority by several organizations concerned with conservation of the biodiversity of the USVI. The Dept. of Interior granted The Nature Conservancy funds for this purpose. The Conservation Data Center (CDC), a consortium of governmental and non-governmental organizations in the USVI, is coordinating the effort. NPS resource managers in Virgin Islands National Park have been collaborating with the CDC.

Maps are also available for DRTO, including the one produced in 1882 by Agassiz and the one prepared by Davis in 1981 (Davis 1982), later digitized by Florida Marine Research Institute. In the last few years, the NPS Submerged Cultural Resource Unit has mapped areas of DRTO using RoxAnn, a bottom classification device.

Comparisons of Aerial Photos (and Maps) using GIS

A series of aerial photographs are available for VIIS, BUIS, and DRTO. Eventually, it will be possible to use Geographic Information System (GIS) technology to quantitatively assess any substantial changes in major features of terrestrial and marine ecosystems in the three parks. For example, Hurricane Hugo (1989) is known to have effectively shifted the southern reef crest at BUIS at least 30 m towards the island and to have reduced the extent of seagrass beds (through scouring and burial). Also, new roads and houses are being constructed every week on St. John. Many of

these changes can be charted through comparison of values from digitization of existing aerial photographs. Scientists with Florida Marine Research Institute have digitized 1992 aerial photos of DRTO. BRD is now trying to arrange for an analysis of major changes in marine ecosystems and island shorelines through comparison of this recent map with the one produced by Gary Davis in 1981 (Davis 1982).

Habitat-specific Inventories

A substantial amount of information is available for certain bays within VIIS which have been the subject of intensive investigations. Coral reefs, seagrass beds, and algal plains in Great and Little Lameshur Bays were the subjects of a series of reports associated with the underwater habitat "Tektite" from 1969-1971. In 1989, permanent long-term monitoring transects were established off Yawzi Point, between Little and Great Lameshur Bays, and inventories of corals, sponges, gorgonians, and algae have been done (Rogers et al. 1991, Gladfelter 1993). In 1990, a long-term monitoring site was established in Newfound Bay, off the east coast of St. John, and inventories of corals, reef fishes, algae, sponges, and gorgonians are available from here (Gladfelter 1993, BRD unpub. data).

An extensive amount of research has been done on the coral reefs off the eastern end of Buck Island, and comprehensive lists of fishes and corals are available (Gladfelter 1992).

In 1989, Florida Marine Research Institute (FMRI) established long-term monitoring sites on 5 reefs within DRTO, collecting data on stony corals, octocorals, and fishes (Jaap and Wheaton 1995).

Marine Organisms

The major groups of marine organisms within VIIS, BUIS, and DRTO, especially those associated with coral reefs, are relatively well-known. A comprehensive list of about 400 species of coral reef fishes, based on collections by John Randall in the 1960's, is available for the VI parks. The list of stony corals is virtually complete, but we lack comprehensive knowledge of octocorals and sponges. Research by scientists and students at the West Indies Laboratory on St. Croix focused on Buck Island for 20 years until the lab was destroyed by Hurricane Hugo in 1989. (Many of the references from the West Indies Laboratory library are now housed at Fort Christian on St. Croix). Information on stony corals and gorgonians at DRTO can be found in Jaap and Wheaton (1995) and Wheaton (1980), while an inventory of sponges appears in de Laubenfels (1936). The list of fish species from DRTO is fairly complete but has not been verified by a taxonomist (B. Smith-Vaniz, pers comm.).

Sea Turtles

Five species of sea turtles are known from DRTO and three from USVI waters (e.g., Small 1982, Mansfield and Reardon 1996a, Hillis 1997). Intensive research on hawksbill turtles (Eretmochelys imbricata), the most endangered species in the Caribbean, has been conducted at BUIS since 1987 with emphasis on nesting require-

ments and nesting success. Threatened green (Chelonia mydas) and endangered leatherback (Dermochelys coriacea) turtles also nest occasionally on Buck Island's beaches. Green and hawksbill turtles are often seen in the waters around St. John, and limited nesting of hawksbills occurs on some St. John beaches (with occasional nesting by greens and leatherbacks).

Threatened loggerhead (Caretta caretta) and green sea turtles nest on DRTO keys. The endangered leatherback has been seen in deep water near the park, while the endangered Kemp's ridley has been reported from the area. Juvenile and sub-adult hawksbills are seen within the park, although adult hawksbills are seldom seen. Relatively complete records of sea turtle nesting within DRTO are available from 1990 to 1996 (Mansfield and Reardon 1996a).

Water Quality

Data on several water quality parameters are available for the waters within VIIS, BUIS, and DRTO (see section below, Marine Monitoring Activities).

Physical Oceanography

Very little information exists on the currents around Buck Island and St. John. Knowledge of current velocities and directions is essential for effective management of marine resources, for example, predicting the transport of sediments, oil spills and other pollutants. Currents transport fish and shellfish larvae and other organisms from upstream sites and therefore play a major role in the recovery of ecosystems after overfishing or hurricane damage. Information on the Tortugas Gyre has been published by Lee et al. (1992, 1994). More studies of currents will be done in all three parks if sufficient funds can be obtained.

Through a cooperative effort with the Florida Institute of Oceanography SEAKEYS program, NOAA, and Florida Marine Research Institute (Florida Dept. of Environmental Protection), an automated environmental monitoring system known as C-MAN has been installed at DRTO. This station is one of seven existing or planned stations in the Florida Keys. Data collected include air temperatures, wind speed and direction, solar radiation, salinity, dissolved oxygen and water temperatures.

Terrestrial Inventories

Flora/Vegetation

The flora of St. John consists of 747 species of native and naturalized vascular plants, with over 85% of them native (Acevedo-Rodriguez 1996). St. John's forests have a very high diversity of native plants. Extensive clearing of the vegetation on St. John (over 90% of the land) during the plantation era, intensive livestock grazing prior to the park's establishment, and introduction of several exotic plants changed the relative abundance of the various species and eliminated some native species. Detailed information on species and their distributions comes from studies in long-term plots in eight different watersheds on St. John (see review in Rogers and Reilly in press). Two of

these plots are part of the Smithsonian Institution's Man and the Biosphere (MAB) Biodiversity network. The Smithsonian and a private sponsor (the Homeland Foundation) collaborated with the New York Botanical Garden to produce an illustrated flora for the island, which is also generally applicable to Buck Island (Acevedo-Rodriguez 1996). Three new species of plants were described recently, with two known only from St. John (Acevedo-Rodriguez 1993). A vegetation map of St. John was produced in 1987 (Woodbury and Weaver 1987). Mossman (1990) compared the usefulness of Landsat Thematic Mapper satellite data and SPOT multispectral data in separating the different vegetation types on the island and produced a series of image classifications.

A survey of Buck Island's vegetation was conducted in 1976 (Woodbury and Little 1976), and a 1996 inventory of the plants on Buck Island added some additional species to the list (Gibney 1996). A vegetation map should be prepared and more data are needed on the distributions of rare plants on the island.

Mammals

Of the approximately 20 species of mammals that inhabit St. John, only the bats are native and little is known of their status in the park. In December 1996, I & M funds were used to support a pilot project on the bats on St. John. A high frequency recorder was used successfully to identify the ultrasonic sound patterns made by different bat species during different activities, a technique that can determine which habitats are being used by bats on St. John. Examination of these sound patterns by an expert suggested that there are at least two more species of bats than previously reported for the island (Petterson 1997). Bats have been observed at BUIS, but no detailed information exists.

St. John has 12 species of non-native mammals that have caused large scale ecological changes on the island. Mongooses were introduced to St. John in 1872 to control rats and have since become naturalized. Large scale reductions in native birds, reptiles, and amphibians may be attributable to mongoose predation. Mongooses continue to prey on sea turtle eggs and hatchlings on St. John's beaches. Feral populations of goats, pigs, and donkeys have been steadily increasing since the 1960's, and continue to pose a serious threat to park resources. Mongooses have probably been eliminated from BUIS, as a result of a 1980 removal project by NPS and FWS, but rats are still present and are known to prey on the eggs and hatchlings of sea turtles and least terns. (During sea turtle nesting season, rats are trapped on BUIS beaches). The destruction from rats stripping bark off some of the trees on Buck Island represents a serious management concern.

Marine mammals, such as humpback whales and dolphins, are occasionally seen in VIIS and BUIS waters. In 1993, two very rare Goosebeak whales stranded on Buck Island. In September 1996, a hooded seal appeared in Maho Bay, off St. John's north shore.

Birds

Shared species of pantropical seabirds provide one of the strongest biological linkages among the NPS areas in this program. The Caribbean seabird guild in oceanic areas associated with these parks includes 17 species, of which 14 nest or occur regularly in and around DRTO and the USVI parks, including tropicbirds, frigatebirds, boobies, and terns. Extensive information on terns and frigatebirds is available for DRTO (Robertson 1964, Clapp and Robertson 1986, Robertson 1996a, b, c).

A comprehensive inventory of birds on St. John, from formal studies and annual Christmas bird counts, has been completed. A study by ornithologists from the Institute of Tropical Forestry, the Nature Conservancy, and Connecticut College is examining population densities of 13 species of neotropical warblers which overwinter on St. John. A population study begun in 1992 focuses on the wading bird community within saltpond and mangrove wetlands on St. John. Pierce (1996) summarized six years of research on sea birds which nest on the small offshore islands of the USVI.

Virgin Islands National Park supports nesting populations of the endangered Brown Pelican and Roseate Terns (federally listed as threatened in the Caribbean). Least Terns, endangered within the Caribbean, are also found in the park. Finally, the Bridled Quail Dove, listed as a globally endangered species, occurs on St. John and on Buck Island. Sooty Terns and Brown Noddies nest at a few locations in the USVI but not within BUIS or VIIS.

Buck Island supports a significant Brown Pelican rookery. Over 30 adult birds nest each season, fledging up to 40 chicks. Least Terns nest on Buck Island's west beach. In 1996, over 200 birds established a breeding and nesting colony on the island, and over 90 chicks were fledged. A single Peregrine Falcon has been observed on Buck Island for the last several winters.

Reptiles and Amphibians

Distributions and relative abundances of reptiles and amphibians on St. John and Buck Island are not well known. No systematic inventory has been done within these parks for at least 10 years. We hope to have BRD herpetologist Ken Dodd visit VIIS and BUIS to conduct surveys of reptiles and amphibians in 1998.

Terrestrial Invertebrates

A list of terrestrial invertebrates on St. John appears in Muchmore (1987), and a comprehensive survey of beetles on Buck Island and St. John is ongoing (Ivie and Clark in press). To date, 460 beetle species are known from St. John including two endemics. Eight endemic species have already been found on Buck Island.

In 1989, an incident of relapsing fever was traced to St. John (Flanigan et al. 1991). An inventory of the ticks, fleas, and mites on mammals on St. John and discovery of any associated viruses would be of epidemiological interest. NIH's Rocky Mountain Laboratory is presently identifying ticks and fleas from mongooses and rats trapped on St. John and Buck Island, testing blood for antigens to Lyme's disease, relapsing fever, and related pathogens transmitted to humans. In 1996, Ornithodoris puertoricensis, a relapsing fever host, was found on Rattus rattus on Buck Island, a range extension for this tick.

Intermittent Stream Beds/Freshwater Communities

The water quality of intermittent freshwater streams within the VIIS has not yet been tested. Sewage and other pollutants may be causing algal blooms observed near the western boundary of VIIS. Contingent upon additional funding, the intermittent streams in affected park watersheds will be analyzed for nutrients and bacteria. Fish and macroinvertebrate populations should also be inventoried and monitored.

Fungi

About 500 specimens of fungi have been collected from St. John to date (Lodge 1997). These include about 175 species of basidomycetes, 50 of ascomycetes, and a few species of slime molds. More than 80% of the species are new records for St. John, and some are undescribed species. It is expected that further examination of collected specimens will reveal additional undescribed species. The new species of basidiomycetes and ascomycetes discovered on St. John are probably found on nearby islands, and it is most likely the relative lack of knowledge of these groups of fungi in the Antilles, rather than endemism, that is responsible for their being unknown. St. John is a very important reserve for these fungi having some of the least degraded moist and dry forest in this region of the Caribbean.

Soils

Scientists from the National Resources Conservation Service (formerly, the Soil Conservation Service) have recently completed a new soil survey of the Virgin Islands, including Buck Island and St. John (NRCS 1995). Soils from some of the long-term vegetation plots on St. John have been characterized.

Computerized data stations, which record soil temperature and moisture readings on an hourly basis, have been installed in four locations in the Lameshur Bay watershed and one in the Cinnamon Bay watershed as part of a regional network of sites intended for long-term monitoring of global climate change (Mount et al. 1995). Solar-powered weather stations at two of these sites record relative humidity, rainfall, wind speed and direction, solar radiation, and air temperature on an hourly basis.

As part of the sea turtle research program on Buck Island, soils from all four nesting beaches have been characterized. Nesting beach temperature at 30 cm below the

surface has been monitored to assist with determining the impact of hurricanes (in particular, the loss of vegetative cover in beach forest nesting habitats) on hatch success.

Air Quality

Under typical wind conditions, no major urban areas are upwind of the USVI for thousands of kilometers. Consequently, air quality is usually very good. Fine particulate matter less than 10 µm is transported to the USVI from the Sahelian region of Africa. This dust at times reduces visibility to less than 3 km. (In the summer of 1993, visibility was so low that you could not see St. Croix from Buck Island, a distance of less than 2.5 km). One of the world's largest oil refineries is located on St. Croix. Volatile organic compounds are released in large quantities from this facility but do not normally reach BUIS or St. John. BUIS may receive some influence from this refinery during summer doldrums and/or wind shifts. A volcano on the island of Montserrat erupted in July 1995 and has continued to erupt sporadically ever since, adding to the particulate matter in the air over the USVI.

VIIS is a Class 1 area. A fine particulate sampler has been in operation since Oct. 1990. The EPA-NPS Demonstration Intensive Site Project (DisPRO) will soon install the following instruments at VIIS: spectroradiometer (for UVB), nephelometer (to detect aerosols), ozone analyzer, dry deposition filter pack system (sulfate, nitrate, nitric acid, sulfur dioxide), an IMPROVE protocol filter system (metals, mass, aerosol composition), and a wet deposition "acid rain" bucket.

St. Croix has two air quality monitoring stations, both located near industrial complexes. Some data were also obtained at the former West Indies Lab. on the east end of St. Croix. If feasible, an air quality station should be established on Buck Island or the eastern end of St. Croix.

Meteorological Data

The USGS maintains a meteorological station near the Biosphere Reserve Center on St. John which records wind velocity, wind direction, solar radiation, humidity, rainfall, temperature, and barometric pressure. This station was installed in 1992. Rainfall and air temperature data have been collected for several locations on St. John over the last several years, and in some cases, decades (NOAA Climatological Bulletins).

In 1996 and 1997, rainfall data were collected during the sea turtle nesting season (June through October) on the south shore of Buck Island. Plans are to collect this information each nesting season.

Data on water temperature are being recorded continuously at several reef sites in VIIS, DRTO, and BUIS using in situ thermisters.

MONITORING PROGRAM DESIGN

The monitoring program proposed here for VIIS, BUIS, and DRTO involves an expansion of existing and prior monitoring with the addition of new projects and an effort to integrate ongoing monitoring activities into a systematic, comprehensive program (see Tables 4,5,6,7). In this section we discuss the major natural resources, the stresses which affect them, and our proposed long-term monitoring activities.

Major Threats to Natural Resources

Threats to the natural resources of VIIS, BUIS, and DRTO include high levels of visitation, damage from recreational and commercial boats, overfishing, oil spills, pollution, and major storms (Tables 8,9,10). Threats to native vegetation which primarily affect VIIS include grazing by feral animals and development.

Development

Development of private inholdings and land adjacent to the park boundary and pressure to re-open old roads within the park represent the most serious threats to the marine and terrestrial ecosystems of VIIS. Clearing of St. John's steep hillsides (over 80% of the island's slopes exceed 30 degrees) and construction of new roads has resulted in elimination of native species, spread of exotic plants, erosion, and forest fragmentation.

Increases in sedimentation from careless development can cause deterioration in water quality adversely affecting coral reefs and other marine systems. Few quantitative data exist on the increases in sedimentation which accompany clearing of steep hillsides in the tropics.

High Levels of Visitation/Damage from Vessels

The white sand beaches and clear waters which contribute to the spectacular beauty of BUIS, VIIS, and DRTO are the major attractions for visitors. Over 1 million people visit St. John each year. Prior to Hurricane Hugo, BUIS had up to 60,000 visitors per year, and annual visitation is now back up to about 45,000. DRTO is more remote, taking several hours to reach by boat from Key West (although it is also accessible by seaplane). It receives about 50,000 visitors a year. Increasing numbers of visitors in all three parks are affecting the natural resources. Damage from snorkelers along the underwater trails at Buck Island and Trunk Bay (St. John) is evident in localized areas but less than the dramatic damage to coral reefs and seagrass beds from boat anchors and groundings. Increased numbers of cruise ships and smaller private vessels have resulted in increased incidents of anchor damage and boat groundings in VIIS, BUIS, and DRTO. Pollution from boats (oil, fuel, human wastes)

represents an unquantified threat to the marine ecosystems in all three parks. Increased boat and seaplane activity at DRTO could adversely affect seabird colonies there.

Documentation of effects of visitation on the resources (e.g., monitoring of numbers of visitors and their use patterns) needs to be conducted as a basis for future management actions. Law enforcement rangers and lifeguards should continue to gather information on numbers of visitors to the parks. Incidents of boat groundings and anchor damage, previously handled almost exclusively by the former VIIS research Division, are now being handled by Resource Management Specialists and Law Enforcement Rangers with support from BRD scientists when needed. Further restrictions on the size of boats allowed to anchor in VIIS, BUIS, and DRTO waters may be warranted.

Marine Monitoring Projects

Monitoring of Coral Reefs

Coral reefs in the USVI and Florida are facing the same pressures as reefs elsewhere in the Caribbean and western Atlantic (Ginsburg 1994, Rogers 1997). Hurricanes, higher than normal water temperatures, and coral diseases have combined with destruction from boat anchors and boat grounding, careless land use, dredging, pollution, and overfishing to cause severe reef deterioration. Several episodes of bleaching of hard corals and other reef organisms have been reported in the last decade for Pacific and Caribbean reefs, and severe bleaching was documented on USVI and Florida reefs in 1987 and 1990. In August 1997, a major bleaching event was observed on reefs off Florida.

Within the last 15-20 years, the amount of live coral has declined while the abundance of algae has increased. The increase in algae probably reflects both an increase in substrate from the death of the coral and the inability of the herbivorous fishes and sea urchins to keep the algal growth in check. Increases in nutrient concentrations may also be stimulating algal growth.

Long-term monitoring of reefs around St. John began in 1989 with the establishment of five permanent transects in Lameshur bay (Rogers et al. 1991, 1997). Similar transects were established off Buck Island at this time. Coral reef research around St. John currently focuses on Lameshur Bay (begun in 1989) and Newfound Bay (begun in 1990). In 1994, preliminary work began in Haulover Bay. The emphasis has been on percent live coral cover and species diversity of hard corals, octocorals, and sponges. This research has been one of the primary activities of the BRD research staff with complementary studies by outside investiga-

tors. These and other sites have provided detailed information on the effects of storms and on recovery of reefs from storms and anchor damage.

Perhaps the most conspicuous change on USVI coral reefs over the last few decades is the decline in elkhorn coral (Acropora palmata), formerly the primary reef-building coral in the Caribbean. Elkhorn coral forms shallow crests near the water's surface, creating physical barriers to ocean waves and reducing coastal erosion. Few large, living colonies of this species can be found now. Elkhorn coral has suffered from major storms and from "white band disease", a disease which has yet to be correlated with pollution or any other human activity. Monitoring of the current status and recovery, if any, of elkhorn zones in all three parks is considered a very high priority. This summer, potentially devastating new diseases appeared on colonies of several coral species, including the dominant reef-building coral, Montastraea annularis, in several bays around St. John. In August 1997, at least one of these new diseases appeared to be present on a few corals in DRTO.

Hurricane Damage

All of these parks have been hit by major storms in the last seven years, with Hurricane Hugo (1989) and Hurricanes Luis and Marilyn (both in 1995) smashing forests and reefs in BUIS and VIIS and the severe storm in March 1993 damaging reefs in DRTO. Hurricanes Bertha and Hortense (both in 1996) also caused some damage in the USVI. Dry Tortugas National Park was spared the devastation of Hurricane Andrew in 1992. Global climate change may result in increased storm activity in the tropics. When ecosystems are disturbed by a combination of natural stresses and detrimental human activities, recovery can be hindered or even prevented. A series of publications are now available on the effects of Hurricane Hugo on VIIS forests and on BUIS and VIIS coral reefs (e.g., Edmunds and Witman 1991, Reilly 1991, Rogers et al. 1991, Rogers 1993, Bythell and Bythell 1992).

At long-term monitoring sites around St. John and Buck Island, the amount of living coral declined drastically after Hurricane Hugo in 1989. Hurricanes Luis and Marilyn hit the USVI in Sept. 1995 and Hurricane Bertha passed directly over St. John in July 1996. No substantial recovery of the Lameshur Bay reef has occurred since Hurricane Hugo. A combination of factors including fishing and additional storm damage from subsequent hurricanes in 1995 appears to be promoting algal growth on St. John reefs and inhibiting coral recovery. Some coral recovery has been observed at Buck Island. In 1997, another coral monitoring site was established along the south forereef at Buck Island to monitor recovery from hurricanes and coral recruitment into this severely damaged area. Video transects and still photographs will be used

to document survival of coral recruits and reef recovery. The 1993 proposal also called for establishment of another coral reef site in an area dominated by octocorals rather than hard corals. The addition of this site is also contingent upon funding. In general, we intend to conduct biological monitoring at our long-term study sites every 6-12 months with greater frequency in the event of a major storm oil spill, or other disturbance.

NPS had the foresight to support long-term monitoring of reefs in all three of these parks well before there was an active I & M program. Consequently, data from coral reef sites in VIIS, BUIS, and DRTO represent some of the best information available on long-term trends on coral reefs in the Caribbean. (Very few studies of reefs worldwide have data sets longer than four years.) Further information on changes in abundance and diversity of species, and in environmental factors over time will come from sustaining the monitoring which was established in coral reef areas in all three of these national parks (e.g., see Rogers et al. 1991; Bythell and Bythell 1992; Bythell et al. 1992, 1993; Jaap and Wheaton 1995).

Sedimentation

Although the physical destruction from hurricanes and white band disease has produced the most drastic changes in the reefs of the US Virgin Islands, other stresses are also taking their toll. Probably the greatest potential threat to the reefs around the USVI is sedimentation associated with runoff from coastal development sites. Current development of private land inside and adjacent to VINP boundaries and construction of new roads has increased the flow of sediment into nearshore waters. BRD scientists are working with scientists from Colorado State University to assess the threats from runoff to marine resources and to develop recommendations for less detrimental land use practices (see below).

In our 1993 proposal, we identified Haulover Bay, St. John, which has a reef with exceptionally high live coral cover, as a very high priority for long-term monitoring because of the potential for degradation from development of the associated watershed. Road construction began in August 1993 along the steep hillside upcurrent and on the eastern side of the bay. In 1994, we began to implement a comprehensive monitoring effort in Haulover Bay to examine the effects of coastal development on both marine and terrestrial ecosystems in a single watershed.

The VIIS boundary cuts through Haulover, and marine and terrestrial resources both inside and outside of this boundary are now threatened by the planned construction of additional roads, driveways, and 30 private homesites. With many lots exceeding 60% slope, the potential for degrada-

tion from erosion and runoff is very high. The developers are required to meet conditions outlined in the permit they received from the Virgin Islands Coastal Zone Management (CZM) Commission. However, the conditions are not very stringent and lack of enforcement has led to long periods of time when silt curtains have been ineffective.

Beginning in early 1994, while road construction was still proceeding, three coral reef transects were established by NBS at the base of the hillside under development (on the eastern side) to provide estimates of abundance and species richness of coral species and other marine invertebrates. Permanent seagrass transects were also established in 1994 and have been monitored periodically to collect data on seagrass density. Data on suspended solids (including sediments) in the water column have been obtained though not on a regular basis.

One way of assessing the input of sediments to marine waters is to examine the percent of land-derived (terrigenous) components in submerged sediment samples. Sediment samples collected from sites above Haulover Bay and from several depths in the bay have been analysed for particle size distribution and mineral composition. Considerable effort has been made to collect sufficient baseline information before the watershed is completely developed to allow better linkage of any changes which are detected with the actual construction process.

We hope that one end product of the studies by BRD and Colorado State University (see below) will be the development of an interdisciplinary, watershed level approach for examining construction projects, determining the effects of construction on nearshore marine ecosystems and improving the efficacy of sediment control measures. Such recommendations will greatly benefit both NPS and the local CZM Division.

Nutrient input

Analysis of submerged sediment samples and of macroalgae from reef sites can provide clues to the role of nutrient input in stimulating algal growth on coral reefs. In 1997, sediment and macroalgae samples were collected from Lameshur, Haulover, Newfound, and "Windspirit" reefs (all off St. John) for analysis of nitrogen, phosphorus, and carbon. Detailed protocols are being developed for these procedures. Additional information on nutrients comes from analysis of water quality samples.

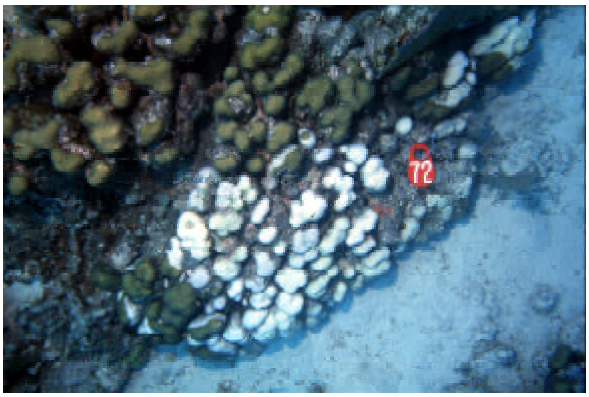
Damage from recreational activities

Virgin Islands National Park attracts close to 1 million visitors a year, most of them arriving on cruise ships or smaller boats. A

single anchor drop from a cruise ship ("The Windspirit") in 1988 led to the destruction of almost 300 m^2 of reef off the north shore of St. John (Rogers 1994). Boats continue to run aground on reefs within Buck Island Reef National Monument and VIIS.

Monitoring of recovery at the site of the "Windspirit" anchor damage will continue. Monitoring reveals no significant recovery of hard corals to date. Monitoring of the recovery following grounding of the "Mavro Vetranic", a commercial vessel, in DRTO should also be continued (Wheaton et al. 1992).

Research on anchor damage led to installation of mooring and marker buoys in VIIS, limits on the size of boats allowed to anchor in park waters, and new regulations which prohibit anchoring in especially vulnerable areas on the south side of the park.



Limited monitoring of seagrass beds near moorings in Salt Pond and Lameshur Bays will help determine effectiveness of moorings (i.e, reduction of anchoring), but there are confounding effects because of storm damage.

Coral diseases/bleaching

Monitoring of reefs in DRTO, VIIS, and BUIS should encompass not only long-term studies but also responses to episodes or events such as coral diseases and bleaching. Monitoring should include documentation of any bleaching or disease events and subsequent recovery of affected organisms, if any. In the summer of 1997, new coral diseases were observed off Florida and at several sites around St. John. BRD is currently conducting detailed surveys of coral diseases off St. John.

Coral recruitment

Some data on coral recruitment are available for all three parks. Size frequency distributions for some coral species are available from Buck Island (Bythell et al. 1992) and St. John (Edmunds and Bruno in press, BRD unpub. data). More data on recruitment are critical for an overview of the status of the reefs in VIIS, BUIS, and DRTO. For example, if coral recruits settle but do not survive to grow into adult colonies, the reefs will not recover from past stresses.

Videography

A primary objective of the I & M program has been to supplement the detailed information available for a few specific reefs within all three parks with baseline information on coral reefs and other marine systems using analog and digital underwater video cameras. Qualitative and quantitative video transects are extremely valuable. Several videos are now available for

VIIS, BUIS, and DRTO including some taken in the USVI before and after Hurricane Hugo and some along permanent study transects.

Videography can provide a substantial amount of useful information while minimizing a diver's time in the water and, unlike several other methods, provides an archivable, visual record of baseline conditions (Aronson et al. 1994, Aronson and Swanson 1997, Rogers et al. 1994). Video transects will be stored using write-to CD. Walter Jaap from FMRI has been providing us with technical assistance on this method. Mr. Jaap, Dr. Jim Porter (Univ. of Georgia) and Dr. Phil Dustan (Univ. of Charleston) are Principal Investigators in the very comprehensive Coral Reef/ Hardbottom Monitoring Project which is being conducted as part of the Florida Keys National Marine Sanctuary Water Quality Protection Plan. They have developed a videographic survey technique which includes detailed image analysis (using customized software) and data management procedures (Wheaton et al. 1996). We will determine if this method is appropriate for the I & M program. As part of this evaluation, BRD biologists Jeff Miller and Brendalee Phillips went to DRTO to work with Walt Jaap and do extensive videotaping in August 1997 on an I & M funded research cruise.

Coral Reef Fishes/Shellfish: VIIS

Natural events and human activities degrade marine habitats, adversely affecting fishes and other species. In the Virgin Islands today, many human activities are damaging coral reefs, seagrass beds, and mangroves. In addition, several devastating hurricanes have degraded reef, seagrass, and mangrove habitats in the islands. The long-term effects on the reef fish assemblages are not yet fully understood. Fishing damages habitats when anchors and traps are set on the reef and lines become entangled on the bottom. Even more important, fishing can directly affect fish abundance, average sizes, and species composition. Many species of fishes depend on reefs for shelter from predation or as a source of food. Others spend their entire lives in seagrass beds, feed in them at night, or use them as nursery areas.

Current fisheries within VIIS and DRTO (and possibly BUIS) cannot be sustained at the present rate of harvest. "Customary" fishing with fish traps of "conventional design" was authorized under the enabling legislation for VIIS while "existing" fishing was authorized within BUIS (outside the fully protected "Marine Garden"). Illegal fish traps are regularly found within the boundaries of the Monument, including within the "Marine Garden", and commercial fishing is now occurring within VIIS and probably BUIS waters. Some fishermen are setting "trap lines" with over 20 traps.

Monitoring of reef fishes

In 1992, the Research Division of Virgin Islands National Park (now the BRD research team) began a study designed to assess the effects of fishing on the reef fishes

around St. John and to elucidate trends in species composition, abundance and sizes of fishes (Beets 1996, Wolff 1996, Garrison 1997). Another objective was to evaluate the effectiveness of park fishing regulations in preserving and protecting the reef fish resource. This initiative involved several interrelated studies which were carried out through the cooperative efforts of a number of agencies and universities. The results to date indicate that fish traps have decreased the number of fishes and changed the relative abundance of species on St. John reefs. The average number of fishes caught per trap and their mean lengths declined. The catch rates and abundances of some of the species with the greatest commercial importance such as groupers and snappers were alarmingly low. A large proportion of the groupers taken by traps are not sexually mature (a sign of "recruitment overfishing").

No differences were found for catch rates, species composition, and sizes of fishes for areas inside and outside park boundaries. About half of the traps surveyed in park waters lacked the required biodegradable panel. Without this panel, lost traps become "ghost" traps, continuing to kill fishes for years. These results suggest that park regulations and enforcement are not protecting a resource which the park is mandated to protect.

Preservation of traditional fisheries and protection of the coral reef and seagrass ecosystems jeopardized by commercial fishing will require careful management. Creation of marine reserves within portions of VIIS and DRTO (now under consideration by NPS, see below) would allow overfished populations to recover and could result in the enhancement of fish stocks in nearby areas outside the reserves. Decisions to restrict fishing will be controversial and must be backed up with excellent, defensible data.

Reef fish assemblages exhibit high variability in numbers of individuals both seasonally and annually, and only long-term monitoring can reveal if abundance and sizes of fishes are declining and if the trophic structure is changing. Annual sampling at 12 reef sites around St. John has been conducted since 1989. More data are needed to elucidate the relationship between habitats and the abundance and diversity of fishes. In addition, density and abundance of groupers and snappers (large predators of commercial importance) will continue to be studied on at least three reefs within the park.

Bait fish are clearly of significance to local fisheries. Surveys around the full moon when these fish are known to aggregate in nearshore waters can be conducted for bays around St. John. This simple monitoring activity can provide very useful qualitative data.

Recruitment of larval fish is known to be highly variable over periods of several

years. To supplement existing data on fish assemblages within VIIS, Dr. Jim Beets worked with I & M biologists in St. John to census fish recruits in reef areas in July 1997. This monitoring will continue on a monthly basis for the next 1-2 years.

Monitoring of lobsters and conchs

Queen conchs (Strombus gigas) support valuable fisheries in the Caribbean. Concerns over overharvesting of this species led to a moratorium in St. Thomas and St. John from 1988 - 1992. In spite of this moratorium, additional regulations in 1994, and a limit of two conchs per person per day for VIIS waters, a recent study shows that conch populations in general appear to be decreasing and density of conchs inside park waters are not significantly higher than outside the park (Friedlander 1996). Conchs were surveyed along transects around St. John and St. Thomas in 1981, 1985, 1990, and 1996 (Wood and Olsen 1983, Boulon 1987, Friedlander et al. 1994, Friedlander 1996). Surveys in 1996 showed that conchs were usually found in seagrass beds. This habitat has been reduced greatly as a result of hurricane and anchor damage. Because conchs have patchy distributions and move over long distances, it is difficult to document and interpret changes in their abundance. However, the evidence of general declines in conch densities at several locations within Virgin Islands National Park and elsewhere around St. John is substantial enough to warrant monitoring annually or biennially at selected locations, including Lameshur, Fish, and Haulover Bays. [Methods presented in Friedlander (1996) will be peer-reviewed]. Lobsters (Panulirus argus) were surveyed in the summer of 1996 for comparison with data collected during previous studies in the late 1960's (during the Tektite program) and the 1980's (Boulon 1987).

Dr. Alan Friedlander (University of Hawaii), Dr. Jim Beets (University of Richmond), and Nick Wolff (who recently completed his Master's degree at the University of Rhode Island) have worked extensively with the BRD to develop protocols for studies of reef fishes and shellfish (lobsters, conchs). These protocols are relevant to DRTO, BUIS, and VIIS.

Establishment of a Marine Reserve

The National Park Service is considering the establishment of a marine reserve within VIIS within which fishing would be prohibited. Reserves are beneficial because they simplify enforcement and protect the spawning stock biomass. They are also thought to supply recruits to fished areas, enhance catches in adjacent areas through emigration, and insure against stock collapse from successive years of poor recruitment (Roberts and Polunin 1991, 1993, Bohnsack and Ault 1996). Many scientists consider marine reserves

to be the most promising fisheries management tool. If there is a decision to go forward with establishment of this reserve, the monitoring of coral reefs and reef fishes within VIIS will be especially valuable for evaluating the effects of reserve designation.

VIIS is in the unique position of having eight continuous years of data on fish assemblages and coral cover. Long-term data from years of multidisciplinary studies at Lameshur provide an excellent basis for evaluating the effects of marine reserve establishment on the south-shore of VIIS. Monitoring the fishes, conchs, lobsters, and living coral on the reefs would provide data for comparisons before and after reserve establishment, data which are not available from anywhere else in the Caribbean.

Channel Islands National Park, under the direction of NPS scientist Gary Davis, is pushing for establishment of new marine reserves. Creation of these reserves in temperate (CHIS), subtropical (DRTO), and tropical (VIIS) parks offers exciting opportunities for comparison.

Coral Reefs/Reef Fishes/Shellfish: BUIS

Future monitoring at BUIS would include continued assessment at all sites surveyed under the NPS Coral Reef Assessment Program (1988-1993). White band disease and storms have severely reduced the populations of elkhorn coral, Acropora palmata, which was the primary framework-building species at BUIS. Expanded monitoring of this species, significant throughout the Caribbean, is proposed. Hurricane Hugo devastated portions of BUIS; some areas were scoured and leveled. Studies of recruitment of hard corals and other reef organisms at these sites will continue.

Studies of the reef fish community structure at Buck Island have been conducted periodically since 1977, and data are available on species diversity, abundances, average sizes of some species, and effects of Hurricane Hugo (e.g., Gladfelter et al. 1977, Gladfelter and Gladfelter 1980, Tobias et al. 1988, Bythell et al. 1992, Gladfelter et al. 1991). Coral reef fishes were censused twice a year at BUIS (from 1989 to 1993) as part of the NRP Fisheries Program. Additional information on trap harvests was obtained in 1994-1995 (see Beets 1996). Information on conch (Strombus gigas) and lobster (Panulirus argus) densities around Buck Island appears in Tobias et al. (1988). Continued monitoring of fish and shellfish will build on this excellent baseline.

Coral Reefs/Reef Fishes/Shellfish: DRTO

Corals, octocorals, and reef fishes have been sampled at five long-term monitoring sites at DRTO by Florida Marine Research Institute scientists since 1989 (e.g., Jaap and Wheaton 1995, Rydene and Kimmel 1995). Additional information is needed on

other sites, notably the elkhorn reef near Garden Key (Jaap and Sargent 1994). The Environmental Protection Agency/National Oceanic and Atmospheric Administration (EPA/NOAA) Water Quality Protection Program for the Florida Keys National Marine Sanctuary has no reef monitoring stations within DRTO. However, protocols developed and tested in this intensive sampling effort have served as a valuable basis for studying reefs in VIIS, BUIS and DRTO (Wheaton et al. 1996).

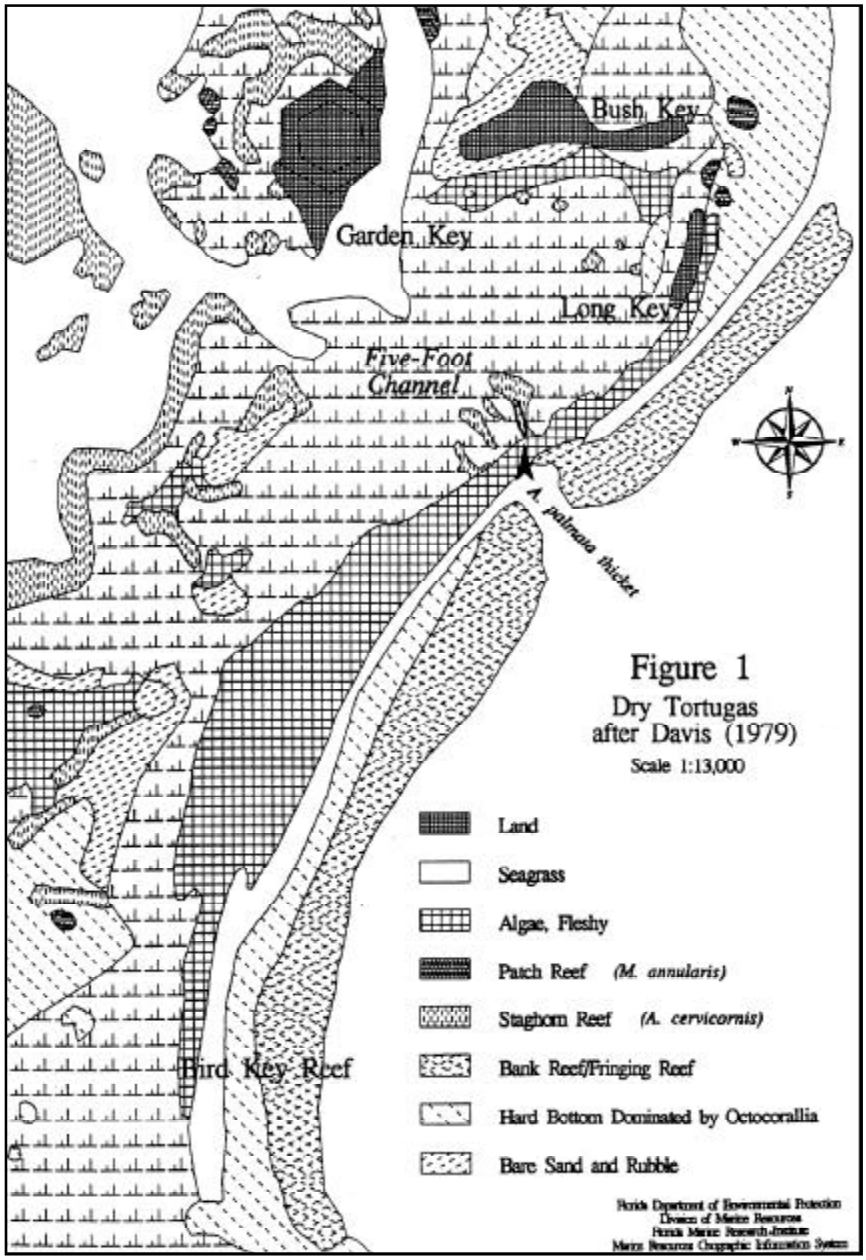


Figure 1
Dry Tortugas
after Davis (1979)
Scale 1:13,000

In 1996, NOAA began installing permanent transects just outside the DRTO boundary as a basis for examining long-term trends in fishes and invertebrates. Similar transects could be set up within DRTO for comparative purposes.

Given the significant fishing pressure observed throughout the Keys and increasingly at DRTO, the comparative value of monitoring at DRTO can not be overemphasized. Presumably because of the park's remote location and the absence of commercial fishing, Dry Tortugas has high numbers of large reef fishes, lobsters and conchs within park boundaries. Big groupers are common within the park. While lobsters and conchs are completely protected, reef fishes are not. Recreational fishing is apparently increasing. Charter boats land several hundred pounds of fish per trip. Adequate protection of the reef fishes within DRTO depends on obtaining estimates of recreational landings and on the existing abundance and density of reef fishes. The National Marine Fisheries Service is now monitoring reef fishes within the park (Bohnsack, pers. comm.). In August 1997, during the I & M sponsored research cruise to DRTO, Dr. Jim Bohnsack and several

assistants censused reef fishes at several sites in and near the park, including the permanent sites established by FMRI.

Monitoring of the lobsters and conchs in the park should be continued. Dr. John Hunt, with FMRI, is comparing the protected spiny lobster populations within DRTO to fished populations along the Florida Keys reef tract.
BRD scientists joined seven scientists from NOAA and Florida Dept. of Environmental Protection on the research cruise to DRTO in August 1997. They videotaped several reef areas, resurveyed quadrats at permanent study sites, censused snappers, groupers and other fishes, and inventoried sponges.

Special consideration should be given to selecting additional reef and seagrass sampling sites within the western portion of DRTO if NPS and NOAA move ahead with designating this area as a marine reserve (as called for in the Management Plan for the Florida Keys National Marine Sanctuary).

Sea Turtles

Threats to the endangered sea turtles in VIIS, BUIS, and DRTO include human disturbance on nesting beaches, erosion of these beaches following storms, mongooses and rats which prey on hatchlings and eggs, collision with boats, and incidental killing by commercial fishing vessels.

Buck Island Reef National Monument

The Buck Island sea turtle monitoring program based on nightly patrols during peak nesting season is now into its tenth year. From 1988 to 1997, over 100 female hawksbills were tagged, and data are available on nesting success, growth rates, fecundity, and nesting site fidelity (Hillis and Mackay 1989, Hillis 1992, 1993, 1994). Since 1988, other research on hawksbills has been conducted to record the effects of three hurricanes on nesting success (Hillis and Phillips in press), to follow movements of the turtles during their internesting interval with telemetry (Starbird and Hillis 1992), to determine migratory behavior using satellites (Groshens and Vaughan 1993), to collect blood samples for analysis of population genetics (Bass et al. 1996), and to examine the effects of loss of beach forest on nest temperatures, hatchling sex ratios, and hatch success (Fortuna and Hillis-Starr in press).

Most recently, studies of juvenile hawksbills foraging in the surrounding coral reef ecosystem have been initiated (Phillips 1996, Mayor et al. in press). Over 40 juvenile hawksbills have been found foraging or residing in the coral reef which surrounds the island. Satellite telemetry data indicate that hawksbill turtles remain within 1 to 2

kilometers of BUIS beaches between nestings and, after nesting, may return to their foraging grounds over 1500km away in Belize and Nicaragua.

Major storms have had serious effects on hawksbill nests. In September 1996, Hurricane Hortense dumped 380 mm of rain on St. Croix. A significant number of hawksbill nests in late development stages suffered a high mortality of full term embryos. The excessive rainfall probably caused the developing embryos to drown. Hurricanes Hugo (1989) and Marilyn (1995) destroyed most of the critical beach forest habitat at Buck Island, the preferred nesting habitat for hawksbill turtles on this island. Fallen trees and the steeply eroded berm have made access difficult for nesting turtles. The loss of vegetative cover and the resultant increased sand/soil temperatures appear to be adversely affecting hatch success. Plans are to do beach profiles twice a year at Buck Island to monitor changes in the shoreline, particularly, losses/gains in the amount of the beach habitat required for hawksbill turtle nesting. Dr. Dennis Hubbard conducted beach profiles at Buck Island in August 1977.

Virgin Islands National Park

Hawksbill and green sea turtles are found in significant numbers off St. John, yet only hawksbills nest regularly on the island. (A single leatherback nest was noted in 1983 and 1994, and two nests in 1997). Intensive monitoring of sea turtles on St. John took place in 1985-1986. More limited monitoring has been done in the 1990's. Recent monitoring of sea turtle nesting on St. John has been organized by NPS resource managers and conducted by volunteers who check 35 nesting areas around the island. About 60% of the annual nesting activities occur at 25 locations within the park. A maximum of 100 activities was recorded in a single year. Under the auspices of the I & M program, the current monitoring protocol is being revised to be as consistent as possible with the protocol currently used at BUIS. There are plans to use the computerized, relational database developed for BUIS for both USVI parks, and DRTO could be included in the future. There is a cooperative effort underway to standardize sea turtle monitoring in all three parks.

In April 1997, Zandy Hillis-Starr, the Principal Investigator for the BUIS sea turtle program, visited St. John and reviewed the VIIS sea turtle program. She worked with VIIS Resource Management Specialists to identify high priority beaches, as defined by the Virgin Islands/Puerto Rico Hawksbill Recovery Plan, and to define objectives for future monitoring. If possible, the beaches on St. John which have supported the most nesting activity to date should be monitored thoroughly for five consecutive years to allow a comprehensive picture of the island's significance as a nesting location.

Dry Tortugas National Park

Since 1980, there has been intermittent monitoring of sea turtles within the boundaries of DRTO. In 1995 and 1996, AmeriCorps and Student Conservation Association members and volunteers conducted daytime nesting surveys on each island throughout the entire nesting season (Mansfield and Reardon 1996a,b). Over 1,000 crawls by loggerheads have been recorded in the last six years compared to 130 for green sea turtles. Adult hawksbill turtles are rarely seen in the park although sub-adults are often observed in the reefs and seagrass beds. An excellent description of the sea turtle monitoring program, with detailed protocols, is available (Mansfield and Reardon 1996a,b).

Seagrass Beds

Seagrass beds are critical foraging habitat for several species of fishes and sea turtles. Seagrasses help maintain high water quality and clarity by trapping sediment particles and reducing shoreline erosion. Monitoring of seagrass beds around St. John has shown that they have been severely degraded by a combination of major storms and anchor damage (Muehlstein 1995). Recovery, if it occurs at all, could take several decades.

Seagrass beds in Great Lameshur Bay are being monitored for changes in species and density, and for recovery of areas scoured by waves during hurricanes. In 1997, monitoring was expanded to include additional sites around St. John. Sampling of permanent transects will be done on a quarterly or semi-annual basis and will provide data on seagrass community structure and densities. With support from the I & M program, Dr. Lisa Muehlstein has continued the monitoring of seagrass beds at permanent transects within Lameshur Bay for the last several years.

Effective September 6, 1993, anchoring was prohibited in Great and Little Lameshur Bays, St. John, and beginning in 1998, anchoring will be prohibited in all south shore bays within the park. Monitoring of the seagrass beds in these bays can help to demonstrate if mooring buoys effectively provide protection to these resources. Dr. Robblee and Dr. Muehlstein are recommending protocols for collecting baseline data and for monitoring seagrasses which will be useful in DRTO, BUIS, and VIIS.

Only very limited monitoring of seagrasses has occurred around Buck Island. As part of a study on sea turtle foraging, benthic habitats around the island, including seagrass beds, will be mapped in a GIS-compatible format.

Dr. Jim Fourqurean, with Florida International University, has been monitoring seagrass beds at 14 stations within DRTO.

Mangroves

BRD biologist Dr. Tom Smith came to VIIS in March 1996 to establish a permanent monitoring plot in the mangroves in Lameshur Bay. He surveyed the effects of the 1994-1995 drought and hurricanes on mangroves here and at several other sites on St. John. If feasible, monitoring of mangroves will be continued.

Monitoring of water quality

The Caribbean Sea is known for its extremely clear water. Sediment from land clearing activities, nutrients from runoff, and sewage from septic tanks, leachfields and boats all can degrade water quality. Less obvious nutrient sources are the upwelling of deep oceanic water which occurs with the approach of severe storms and the seasonal discharge of sediment-laden continental rivers. Two factors contribute a seasonal influx of nutrients to St. John's waters:1) heavy rains wash soil, animal feces, and organic debris from areas which are being cleared for development down into the intermittent stream beds on the island and into the ocean; 2) the Orinoco River discharges its nutrient-laden water into the SE Caribbean where, during southerly winds, it is carried in currents which flow towards the USVI (Muller-Karger et al. 1989). An influx of nutrients can cause phytoplankton blooms and algal overgrowth on coral reefs. Suspended sediment (or a phytoplankton bloom) directly blocks sunlight, decreasing the amount of photosynthetically active radiation reaching a reef, adversely affecting plants and reef-building coral.

Since 1988, VIIS biologists have been gathering data on temperature, pH, conductivity, salinity, dissolved oxygen, turbidity and transmissivity of the marine waters at 30 sites around St. John. For the past three years, nutrient (nitrate, nitrite, DIN, ammonia, and phosphate) concentrations have been determined monthly and extinction coefficients calculated periodically. A flow-through fluorometer has recently been loaned to VIIS from Biscayne National Park; a planned pilot study will determine whether the instrument is capable of detecting the low concentrations of chlorophyll *a* in VIIS waters. Nutrients are known to be rapidly taken up and tightly recycled in the water column and the substrate; thus, to obtain a more complete picture of nutrients in reef waters, data on nutrient and chlorophyll *a* concentrations in the water column and nutrients in sediments and benthic macroalgae will be collected.

To date, VIIS water quality remains generally good, but, initial analysis shows higher turbidity near developed shorelines. Nitrate and phosphate concentrations are normally near detection limits, except in bays with developed watersheds; as expected, ammonia levels are higher (but not high) in mangrove areas, which are reducing environments.

In 1995 the Water Resources Division (WRD) of NPS checked, verified and entered all VIIS WQ data through 1994 into a STORET database, then summarized the data (NPS WRD 1995b). We requested WRD's recommendations for improving our

water quality program. Also, Drs. Candace Oviatt and Scott Nixon of the University of Rhode Island reviewed the data sets and the joint WRD/VIIS proposed sampling design and protocols. The proposed changes include: fewer sites sampled monthly; replicates at all sites; chlorophyll *a* determinations as well as nutrients in sediments and benthic algae; regular determination of extinction coefficients; monthly testing for Enterococcus or fecal coliform at Trunk Bay (Class A waters). The design and protocols have been approved. The new sampling design was implemented in March 1997 (with the exception of chlorophyll *a* and bacteria). The VIIS Division of Resource Management took over the primary responsibility for water quality monitoring around St. John in early 1996. A BRD/USGS marine biologist trained the RM Specialist Trainee at VIIS, and continues to assist when necessary.

Monitoring of water quality at two Buck Island sites has been conducted for 20 years by the local government and EPA. Quarterly data exist on fecal coliform, turbidity, salinity, dissolved oxygen and temperature. If funding and staffing permit, water quality (including nutrients and bacteria) should be monitored at Buck Island by NPS staff on a quarterly basis.

If possible, suspended matter concentrations will also be sampled at Buck Island and St. John water quality stations as an indication of the amount of sediment in the water column. This will be done in conjunction with measurements of turbidity and extinction coefficients.

The Dry Tortugas are the first land masses along the Florida reef tract to receive nutrients, pesticides, and other pollutants from the waters of the Gulf and Central America. It is critical to monitor water quality within DRTO, with emphasis on nutrients and chlorophyll. The Florida Keys National Marine Sanctuary has started a water quality monitoring program for the sanctuary and the waters within the park. DRTO is considered critical in this system-wide monitoring scheme because of its comparative value as a relatively undeveloped site. Dr. Ron Jones, Florida International University, is sampling water quality at 150 stations from just south of Miami to the Dry Tortugas, including 13 within or adjacent to DRTO. Long-term monitoring of water quality is considered a very high priority for DRTO.

Terrestrial Monitoring Projects

Erosion/watershed Studies

In 1993, Colorado State University scientists Don Anderson and Lee Macdonald began a study of sediment sources and erosion susceptibility for different areas on St. John under a Cooperative Agreement with the NPS Water Resources Division. Their field measurements indicated that St. John's long history of human uses, including plantation agriculture in the 18th and 19th centuries, substantially accelerated sediment loss on the island. They concluded that the grow-

ing number of unpaved roads on the island constitutes the largest source of sediments today. The CSU scientists produced a preliminary GIS-based model to help assess erosion rates (Anderson 1994). Further work by Rob Sampson, also with CSU, is helping to fine-tune this model and to quantify the rate of sediment loss from vegetated and cleared hillsides. NPS has provided about $50,000 to support additional work on sedimentation on St. John. The overall goal is to use empirical data to link events across spatial scales (from sub-plots to watersheds) and more accurately quantify sediment delivery processes from different areas on St. John which receive various amounts of rainfall and to develop a model which can predict changes in erosion and sediment delivery rates to nearshore waters with different land use patterns.

BRD scientists have collected sediments from the hillsides above Haulover Bay and submerged sediments for analysis of particle size distribution. Data on particle size distribution, N:P:C ratios and mineralogy are available. Increases in land-derived sediments in the bay can indicate upland erosion.

VIIS and BUIS Forests

Permanent forest plots have been established in a variety of ecological zones on St. John to investigate regeneration, recruitment, and mortality of tree species; decomposition rates of leaf litter and woody debris; as well as the possibility of restoring a degraded forest ecosystem (Weaver and Chinea-Rivera 1987; Reilly et al. 1990; Reilly 1991; Ray 1993; Weaver 1994, 1996). These forest plots represent a continuum from lowland elevation dry forest to upland moist forest. The following vegetation types are currently included in the monitoring program on St. John: upland moist forest, gallery moist forest, dry semi-evergreen woodland, and dry evergreen scrubland. Vegetation plots were established by researchers from the Smithsonian, the University of Georgia, and the International Institute of Tropical Forestry. Monitoring of these plots allows quantification of changes from the severe drought in 1994-1995 and from the series of hurricanes which have affected St. John, with three especially severe storms in 1989 and 1995.

The Smithsonian's MAB Biodiversity Program, of which Dr. Francisco Dallmeier is the Director, has published protocols on long-term monitoring of vegetation which may serve as a basis for all of the vegetation monitoring on St. John and Buck Island. Dr. Anne Reilly has been conducting vegetation monitoring on St. John since 1986. Dr. Pete Weaver, from the International Institute of Tropical Forestry, returned to St. John in July 1996 to examine the vegetation plots he has been following since 1983. The Friends of Virgin Islands National Park provided funds for Eleanor Gibney, a botanist on

St. John, to assess the effects of the severe drought of 1994-1995 on vegetation in one of the plots established by the Smithsonian.

Ecosystem processes other than succession and regeneration have been under-represented in research on St. John. Additional funding for I & M activities could be used to monitor net primary productivity, organic matter accumulation, and nutrient cycling. It may be possible to arrange with the International Institute of Tropical Forestry for the use of St. John as a satellite site for the Luquillo National Forest LTER site in Puerto Rico. All existing permanent vegetation plots will be censused every five years, with more frequent maintenance as needed (replacement of plot boundary markers, tree tags, etc.). Successional processes will be monitored to examine the rates of growth, mortality, and recruitment of all seedlings, saplings and trees, and recovery following hurricanes.

Buck Island was subject to extensive clearing of hardwoods in the 18th and 19th centuries. Once called "Isle Verte" (Green Island) by the French for its dense lignum vitae (Guaiacum officinale) forest, it was subjected to deforestation, burning, and grazing by goats. The vegetation on Buck Island is now recovering from these stresses. We are considering establishing a long-term vegetation monitoring plot on Buck Island. The island serves as a natural reference site (an "exclusion" study) for increasing our understanding of the effects of feral and exotic animals on dry forest plants. Following site selection and the mapping and identification of all trees within the plot, monitoring could be conducted every three to five years.

Feral and Other Introduced Animals

Feral populations of goats, pigs, and donkeys have been steadily increasing since the 1960's and pose a serious threat to native plants in VIIS. On St. John, pigs have rooted through the permanent vegetation plot established in Bordeaux, and another research plot on Mary Point has suffered from grazing by donkeys. Donkeys create networks of trails causing soil erosion on steep slopes and facilitating the growth of exotic weeds. Donkeys also selectively graze on seedlings of certain native tree species. Goats have created scrublands where diverse, dry evergreen thickets once thrived.

Wild pigs are threatening the population of one plant species which has been federally listed, Calyptranthes thomasiana. Recently, NPS funded a survey and a population study of these endangered plants. The park plans to identify and implement measures for controlling the pigs in the Reef Bay and Bordeaux watersheds.

NPS does not place a high priority on further monitoring of donkeys and other feral animals populations at this time. There is sufficient information on the destruction they cause (grazing on native vegetation, etc.). NPS and the local V.I. government will be working on a management plan for these animals.

Exotic Plants

Exotic plants are a major and increasing component of the vegetation on VIIS and BUIS. Scientists working on St. John have expressed concern over several species of exotics which appear to be encroaching on native species, although hard data are lacking. Feral animals contribute to the spread of exotic plants.

If additional funds can be obtained, experiments will be implemented in one or more of St. John's "Genip" (Melicoccus bijugatus) groves to 1) track the expansion of existing populations, 2) to test ecological restoration methods, such as underplanting existing "Genip" canopies with native tree seedlings, and 3) to test the usefulness of seedling, sapling, and tree removal of "Genip" in converting groves to more diverse native species assemblages.

Native Mammals

Information on the distribution of bats will be obtained from all major vegetation types in VIIS. Later studies will concentrate on assessment of food habits and attempt to estimate populations.

Reptiles and Amphibians

The major impacts to reptiles and amphibians in the USVI occurred following introduction of mongooses to the islands in 1872. Extant threats include continued predation from mongooses, and accidental introductions occurring from stowaways on imported plants used for landscaping in areas near and within VIIS. Agricultural inspections of plants coming into the Virgin Islands through customs is cursory at best, and no inspections are done on cargo transported between the Virgin Islands. Consequently, accidental introductions are inevitable. Two species of frogs have already been introduced to St. John. Because St. John is separated from St. Thomas by a narrow three mile channel, and there is constant movement of cargo between the two islands, odds are very high that other species which have already been introduced to St. Thomas will reach VIIS. A thorough inventory of the herpetofauna of St. John is needed, followed by monitoring of rare and introduced species. Recent introductions of the Cuban tree frog and Puerto Rican coqui to the island have already been confirmed.

Birds

Development of private lands within VIIS and elsewhere on St. John and construction of roads through watersheds which are now largely undisturbed could have drastic consequences for birds which winter in the Virgin Islands. Monitoring on St. John has revealed that the island has one of the highest concentrations of

migratory songbirds of anywhere in the Caribbean.

Migratory songbirds

Research over the last 10 years on St. John has shown the importance of having intact forest as winter habitat for migratory songbirds (Askins et al. 1992, Askins and Ewert 1992). The relatively intact forests of St. John contained higher densities and richer species diversity of warblers than the fragmented forests of neighboring St. Thomas. With the exception of a project in Puerto Rico that has been running since 1972, this work is the first systematic monitoring program of winter-resident birds in the West Indies. Some warbler species appear to be declining. Future monitoring will help to determine if hurricanes, the 1994 drought, or natural fluctuations in bird or insect prey populations are responsible for the observed trends.

The point census technique which is being used to monitor migratory songbirds is a standard technique which has been used since the early 1970's. Dr. Bob Askins and Dr. Dave Ewert have been developing the protocol for sampling of the insects that many of these species feed upon. Their protocol has already been used by others in the tropics.

Following protocols developed by Drs. Askins and Ewert, spring and summer point count surveys will be conducted on pigeon and dove species, especially the Bridled Quail Dove, which is considered threatened worldwide. These surveys will also provide excellent information on the status of St. John's resident species.

Seabirds and shorebirds

The Brown Pelican (Pelecanus occidentalis) colonies within VIIS and BUIS will continue to be monitored. Within VIIS, pelicans will be monitored on a biweekly basis during the peak of nesting season, usually winter. If breeding birds are present, numbers of nests and individuals (classified by age class) will be counted. Monitoring may be reduced to monthly intervals depending upon reproductive activity.

Biologists at BUIS, Everglades National Park, and the Virgin Islands Dept. of Planning and Natural Resources will be consulted to develop a monitoring protocol that will provide standardized data for regional analysis of Brown Pelican populations. A Recovery Plan has been published for the pelican population in the Caribbean, and some monitoring is conducted by NPS and the USVI Division of Fish and Wildlife (DFW). It is a priority for NPS personnel to conduct consistent monitoring of Brown Pelicans.

Roseate Terns, on the federal list of threatened species, nested within VIIS in 1997

at Rata and Ramgoat Cays. In 1997, all of the nests on Rata suffered heavy predation. The population on Ramgoat Cay represents the first documented attempt by these terns to colonize this island and constitutes the single largest colony in the US and British Virgin Islands. When Roseate Terns are found in VIIS, DFW is notified, and US Fish and Wildlife Service personnel based in Puerto Rico travel to St. John to monitor the colony, counting nests and eggs and banding adult birds. Park personnel assist with this endeavor. Continued cooperation among the various agencies will be maintained, and if possible, the primary monitoring effort will be implemented by NPS. Other offshore cays are to be monitored for seabird nesting, including the recording of nesting Tropicbirds in coastal cliffs. Pierce (1996) prepared a report summarizing information on seabird nesting in the US and British Virgin Islands, including within VIIS.

Least Terns are monitored on BUIS every year beginning in April when the birds first begin to arrive on the island. Visual censuses are done 1-2 times per week. After the colony is established and mating occurs, NPS encloses the area to keep visitors away from the birds. Monitoring of nesting pairs and nests continues for two months or more until the last chick departs the island. Injuries to eggs or chicks from rats are also recorded.

Additional surveys are needed for seabird, shorebirds, and wading birds that use park habitats. Of particular importance are the birds associated with mangrove forests, since the latter have declined significantly from recent droughts and storms. If feasible, shore birds and waterfowl within VIIS will be counted every week at selected salt ponds and mangrove areas from August through May, and then monthly.

Plans are to consult with biologists at Everglades National Park and BUIS to identify ways to share information on seabirds and shorebirds and to develop management strategies. Staff at VIIS will become more involved with the Society of Caribbean Ornithology and the national Partners in Flight program to address regional bird conservation issues and to encourage the need for habitat preservation through establishment of preserves or parks.

Dry Tortugas National Park provides critical habitat for several species of seabirds. Seabirds at Dry Tortugas have been largely protected for almost 100 years. The park supports the only breeding

colony of Brown Noddies in Florida, and the only consistently active breeding colony of Sooty Terns and Magnificent Frigatebirds in the continental U.S. (Robertson 1964, 1996a, b, c). BRD biologist Dr. Bill Robertson has conducted comprehensive long-term studies of birds in DRTO, especially the terns, and has recently summarized much of his research (Robertson 1996b,c). He notes that birds in the park, although afforded a very high level of protection, are still vulnerable because of storms, loss of nesting habitat with expanding ground cover on some keys, and disturbance from increasing visitation. Every effort should be made to continue monitoring of seabirds in DRTO.

Recreational Use/Visitation

Monitoring of the numbers of people who visit VIIS, BUIS, and DRTO should continue. BUIS will continue to monitor the effects of heavy use of the underwater trail.

DATA MANAGEMENT

The primary mission of the I&M program is to provide park managers with scientifically-based and statistically valid data upon which resource management decisions can be based. Good data management facilitates effective resource management by making data readily available to evaluate ecosystem status, diagnose abnormal conditions, contribute to the knowledge needed for park planning and actions, and to identify critical issues. The objective of data management is to create accurate, useful and secure data which are available to those who need it. The optimal system should be simple; flexible and easy to use; produce accurate, precise data; and permit integration of different data sources (Dye 1997).

Computer Protection

Electrical power at VIIS and BUIS is highly unreliable and may have spikes to over 180 v. All computers are protected by large UPS (uninterrupted power supplies) systems. Printers are protected by surge protectors. For long periods without electricity, an emergency generator (10 KW), transfer switch and diesel fuel tank were purchased by NBS; the genset runs computers, lights, telephones, fax, printers, etc. in both the office and laboratory buildings.

Existing Datasets

Most VIIS data are in QuattroPro spreadsheets and are not spatially referenced. No GPS base stations exist in the Virgin Islands and VIIS NPS RM has only one GPS unit. Once a second unit and appropriate software are purchased, spatial data can be collected for most study sites, which are permanent. Spatial data taken to date at VIIS are inaccurate.

QA/QC and Metadata

The Data Management Plan is in its first draft, and nearly all data sets are entered in a standardized format to facilitate integration. Metadata will be entered using the NPS Dataset Catalogue format. At present, only very cursory documentation exists for the VIIS datasets. Some field data sheets have been formatted to correspond to spreadsheet formats to minimize data entry errors. Range limits are included on some field data sheets so that data collectors are alerted to check instruments or review procedures in the field. All field data are copied into a notebook by the person who collected the data, and photocopies of original data sheets are archived on site. Optimally, field data collectors enter their data directly from original data sheets into a standardized computer spreadsheet and double check entry accuracy. The "data manager" then checks for entry accuracy and verifies data. (Currently, BRD Biologist Ginger Garrison is working on data management as time allows. No Data Management Specialist has been hired for the program.) The verified master data set is copied onto the hard drive of the archive computer and a backup copy made on a ZIP disk or tape and stored on site. Hard copies of original data in field notebooks are stored at the BRD Scientist's residence. Eventually, all master datasets will be copied onto CD and stored at an offsite location not subject to the same natural disasters as the VI and Florida. The process of changing from QuattroPro and Paradox software to Excel and Access, the new NPS standards, is underway.

In an attempt to improve QC, a high resolution digital video camera and board for direct uploading onto a hard drive have been purchased. By archiving individual frames of a transect on CD, species identifications can be verified and a visual record of the reefs will exist on stable medium. Also, the archived images can be sent electronically to other researchers for quality assurance.

Data security is a concern. The Windows95 operating environment does not provide sufficient security to prevent accidental corruption of data. Our present security system consists of backup copies which are periodically checked. To enhance security, the computer which is used for archiving, most analyses, backup, and video capture may be changed to a Windows NT operating system.

Data Analysis

Project directors have primary responsibility for data analysis on new projects. Two BRD biometricians (Drs. Paul Geissler and Robert Dorazio) have been consulted regarding the experimental designs of our primary, ongoing studies, and we will continue to seek their advice. The VIIS water quality dataset has been summarized and reviewed by the NPS Water Resources Division.

Geographic Information Systems

VIIS has an approved GIS Plan that identifies GIS objectives, staffing needs, data priorities, and available data. The primary software packages used are Arc-Cad, Arc-

View, and IDRISI. As of November 1993, VIIS had 17 coverages that were digitized and operational on a Data General Arc-Info based system at the USGS office on St. Thomas (the office has since been closed). The following coverages were transferred from USGS to the VIIS GIS: vegetation map, marine benthic communities, hydrography, land contours, geologic features, soils map (reclassified since then), archeological sites, historical buildings, T & E species, land status, water and sewer lines, buildings, boundaries, the western 50% of the ocean bathymetry, roads and trails, study site location and wildlife observations. Since Fall 1994, no one has been available to maintain the GIS database; the software and data are on a computer used by six employees and visiting scientists. Some of the coverages are corrupted and others need to be updated - work which is beyond the training and capabilities of the present staff.

VIIS is in the process of upgrading its GIS. The RM Division plans to maintain a Windows95/Arcview 3.0 system, with support from NPS and technical assistance from the Center for Conservation of Data at the University of the Virgin Islands, North Carolina State University, and NPS personnel nationwide. Long-term support is essential for maintenance of a functioning GIS. We will have to decide whether the DRTO data would be better maintained within the VIIS GIS or the GIS at Everglades National Park.

PROTOCOL DEVELOPMENT/EVALUATION/SELECTION

The protocols in the VI/Florida I & M program range from those which have already been published (for example, some of those used to monitor vegetation and coral reef organisms) to those which scientists are just beginning to develop (those on insect prey populations, coral colony sizes and diseases). In almost all cases, even where the methods are standardized, there is a need to determine the frequency of sampling, the necessary number of samples, and the need for adding new locations in each of the three parks. It is important to recognize that the selection of protocols for long-term monitoring in national parks must be driven by the management questions which are being addressed and the information which is being sought. Some protocols may be well-designed and scientifically rigorous but not appropriate. An attempt should be made to use methods which are relatively simple and repeatable. The word “monitoring” refers to an entire range of activities of varying difficulty and complexity. Monitoring of environmental factors such as temperature is less challenging than biological monitoring which requires SCUBA diving and identification of all species encountered. In some cases, monitoring can be automated and there is a need to calibrate and maintain the equipment.

Whenever feasible, we will have teams of I & M participants from all three parks working together in the field to ensure that the protocols which are being developed are suitable and to ensure that techniques are standardized where appropriate.

All of the protocols should be published eventually in a manual similar to the one produced by Channel Islands National Park. Each published protocol must provide the rationale for selection of particular organisms and environmental factors for monitoring, as well as the objectives of the monitoring.

A technical advisory committee will be formed to assist with the program. The following people have already agreed to serve on the Committee— Gary Davis (NPS), Charley Roman (BRD) and Jim Bohnsack (NMFS).

OUTREACH

The overall goal of the I & M program is the design and implementation of long-term monitoring programs which provide the information park managers need to better manage natural resources in national parks. One success indicator is the effective transfer of information to park superintendents and others via informal and formal presentations and in clear, understandable written reports. We will continue to make a concerted effort to inform not only park managers but other park employees and members of the community about the activities and results of the I & M program. We consider it especially important to involve NPS Interpreters in this program, and we have been working with VIIS interpreters on an exhibit on I & M activities for the VIIS Visitor Center. In addition, we will continue to hold informal slide shows for park interpreters on our activities. We have already published two issues of Tropic BiRD, the newsletter for the program, and we plan to produce these twice a year. We will continue to provide articles and information for the VIIS newspaper and the local newspapers. We have begun to design a series of one page Fact Sheets. We will also continue to provide updates on the program to park and BRD employees and other interested people using electronic mail.

Finally, we are currently talking to Dr. Francisco Dallmeier from the Smithsonian Institution about holding a major scientific conference on long-term monitoring of marine and terrestrial resources in 1999.

SPECIFIC IMPLEMENTATION STRATEGY

The BRD research team stationed on St. John will assume the lead role during the developmental phase of this program. The three scientists on this team (Dr. Caroline Rogers, Virginia Garrison, and Jeff Miller) have considerable experience and expertise in marine ecology (particularly coral reef ecology) and water quality issues, as well as the associated monitoring methods. Another biologist will be hired in 1998. This core group collaborates with several scientists with complementary expertise, e.g., on seagrass beds.

The other BRD I & M employee, Brendalee Phillips, is stationed on St. Croix working

on sea turtle and reef monitoring under the supervision of NPS Resource Management Specialist Zandy-Marie Hillis-Starr. BRD has continued to support terrestrial ecologists and botanists who initiated long-term vegetation monitoring with NPS support in the 1980's. The 1993 I & M proposal called for nine new positions and an annual budget of over $500k for 5 years. With budget cuts to about $200k per year, the number of positions is not likely to exceed the three hired in early 1997.

The BRD research team works closely with Keith Watson, the Chief of the Resource Management Division at VIIS, and Ries Collier, the I & M Coordinator. NPS and BRD agree that the next highest priority is the hiring of a Data Management Specialist. No decision had been made on this position as of the completion date for this plan (September 1997).

At present, DRTO does not have on staff a natural resource specialist to develop, coordinate, or implement a cohesive I & M program. Robert Brock, the marine biologist for Everglades National Park, has been named as the NPS contact person for I & M activities at DRTO, but he is not in a position to dedicate the necessary amount of time to implement I & M at DRTO. NPS and BRD will need to decide whether someone should be hired during the developmental or the operational phase of the I & M program or whether responsibilities can be rearranged so that someone at Everglades National Park can play a larger role. The hiring of a terrestrial ecologist for the USVI parks is also considered a high priority. Full implementation of the program outlined in this document will require hiring of additional personnel and additional funding.

Ries Collier, the I & M Coordinator, has prepared a Transition Plan (now under review) which describes different approaches which can be taken in transferring responsibility for park monitoring programs from BRD scientists to NPS resource managers. This transition from the developmental to the operational phase of monitoring is extremely challenging and will require effective collaboration of the two agencies.

BUDGET

Given current uncertainty over the funds available from BRD and NPS for the I & M program, and the time it will take for the various monitoring activities to become operational, only very preliminary budget information can be presented here (see Tables below). To date, BRD has provided $381k for the I & M program (in addition to the salaries of three biologists at the VI Field Station). To continue the core program (salaries of I & M employees and research support) as outlined in this Implementation Plan would require more than the anticipated amounts of funding (see BRD budget below, Total Required and Total Anticipated). The tentative BRD budget indicates partial salary for a Data Management Specialist, although this salary may be available from NPS. (The filling of this position is considered critical to the success

BRD BUDGET I & M PROGRAM FOR VIIS, BUIS, DRTO (in thousands)

	YEARS				
	1	2	3	4	5
Biologist GS-9	27.0	47.0	47.0	49.0	50.0
Biologist GS-9	27.0	47.0	47.0	49.0	50.0
Secretary GS-5	17.0	31.0	31.0	32.0	33.0
Biol. Tech. GS-4	7.5	7.5	7.5	7.5	8.0
Biol. Tech. GS-7	9.0				
Data Manager GS-11		(15.0)	(25.0)	(26.0)	(27.0)
Subtotal	87.5	147.5	157.5	163.5	168.0
Research Support	20.0	20.0	25.0	25.0	25.0
Contracts	35.0	25.0	35.0	35.0	45.0
Equipment	21.0	5.0	30.0	5.0	5.0
Travel	4.0	4.0	4.0	4.0	7.0
Supplies	5.0	3.5	3.5	3.5	4.0
Dive Physicals	1.0	1.0	1.0	1.0	1.0
Training	1.5				
Meetings				40.0	25.0
Total Required	175.0	206.0	256.0	277.0	280.0
Total Expected			200.0	250.0	275.0

NPS I & M BUDGET FOR VIIS, BUIS, DRTO (in thousands)

	YEARS					
	1	2	3	4	5	6
I&M Coordinator	70.0	72.0	74.2	76.5	78.8	81.2
Data Manager		54.0	55.6	57.3	59.0	60.8
GIS Specialist		54.0	55.6	57.3	59.0	60.8
Bio. Tech 1			36.6	37.7	38.8	40.0
Bio. Tech 2				37.7	38.8	40.0
Bio. Tech 3						40.0
Bio. Tech (Seasonal)						13.0
Bio. Aid (Seasonal)			7.5	7.7	8.0	8.2
Administrative Clerk				34.0	35.0	36.1
Subtotal	70.0	180.0	229.5	308.2	317.4	380.1
Supplies			2.0	2.0	3.0	3.5
Hard/Software		12.0	6.0	9.0	10.0	7.0
Lab/Field Equipment			3.0	7.0	6.0	6.0
Boat and Support			55.0	4.0	4.0	4.0
Vehicle			25.0	1.5	1.5	2.0
Travel		9.0	15.0	15.0	5.0	19.0
Interagency Trans.						35.0
DRTO Annual Survey						25.0
Subtotal		21.0	106.0	38.5	29.5	101.5
TOTAL	70.0	201.0	335.5	346.7	346.9	481.6

of the program.) Other major items in the BRD budget include support for two I & M meetings, one in conjunction with the Smithsonian Institution and a smaller meeting the following year. Funds are needed for travel support for participants and for covering the publication costs for proceedings. Annual meetings would be very beneficial, but they are considered too costly. The "Contracts" category includes support for research at DRTO, publication of protocols, and other items. Only minimal amounts are shown for training and staff travel.

The NPS budget shown here reflects salaries for the I & M Coordinator, a Data Management Specialist, a GIS Specialist, an Administrative Clerk, and biological technicians who will assume responsibility for monitoring activities as they become operational. Support for a research cruise to DRTO, similar to the one which took place in August 1997, is indicated. The Interagency Transfer category reflects the need for technical assistance from BRD or other scientists with interpretation of monitoring data and review/revision of protocols as necessary. Some funds are shown for purchase of a boat and a vehicle. More details on this preliminary NPS budget appear in the Transition Plan that Ries Collier has recently submitted for review.

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PHOTO CREDITS

Page 5, aerial view of St. John (NPS files); page 6, aerial view of Buck Island (D. Hubbard), aerial view of Dry Tortugas National Park (postcard by R. Gould); page 11, pelican (NPS files); page 14, road above Haulover Bay (R. Dunsmore); page 16, elkhorn coral (V. Zullo); page 17, development above Haulover Bay (R. Dunsmore); page 18, cruise ship (NPS files); page 19, diseased coral (J. Miller); diver with video camera (E. Link); page 20, fisher (J. Sneddon); page 21, rock beauty (J. Brooks); page 22, french grunts (B. Nyden); page 25, diver with turtle (Z. Hillis-Starr); page 26, hawksbill sea turtle (P. Mayor); page 27, diver measuring seagrasses (V. Zullo); page 29, researcher studying erosion (R. Sampson); page 30, researcher examining tree tag (K. Saari); page 32, Northern Parula (B. Dyer,

Cornell Lab. of Ornithology); page 33, least terns (S. Zankl); page 34, sooty terns (J. Pierce).

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